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Sensor Updates for Bigheaded Carp-Tracking Autonomous Boat

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HONORS THESIS

Certificate of Approval

Sensor Updates for Bigheaded Carp-Tracking Autonomous Boat

Jordan Kaufmann
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Engineering Physics

Approved to fulfill the
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Sensor Updates for Bigheaded Carp-Tracking Autonomous Boat

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Abstract

Bigheaded carp are an invasive species that overpopulate and compete with the native species of Kentucky Lake as well as many other North American aquatic ecosystems. The movement patterns of Bigheaded carp are being studied nationwide by the United States Geological Survey and multiple universities. These studies ultimately seek to control their spread and reduce or reverse the ecosystem destabilization caused by this invasive species. Such studies are currently conducted manually on Kentucky Lake by graduate students affiliated with the Murray State University (MSU) Biology Department and Hancock Biological Station, and these manual studies are an arduous and time-consuming effort. To perform these studies more efficiently, Engineering Physics students at MSU's School of Engineering are developing an autonomous vessel that currently includes a small pontoon-style boat, a trolling motor, base electrical systems, and a ProNav GPS navigation module. Work is ongoing to integrate the ProNav module with hydrophones currently used to identify and track the tagged fish and a depth finder to allow for safe and effective navigation of the autonomous system toward tagged Bigheaded carp. This navigation will be directed by a mechanical arm containing a NEMA-17 stepper motor, a Vemco directional hydrophone, an ultrasonic transducer, and an onboard computer. Sensor selections for the hydrophone and depth finder, as well as analysis of the torque exerted on the hydrophone during operation, and the implementation of the transducer for the use of a depth finder, will be the focus of this paper. The sensor selection and torque analysis combine to form a critical step toward launching C-TAB (Carp-Tracking Autonomous Boat) in a bay and autonomously tracking and navigating toward a V16TP ultrasonic tag safely.

Nomenclature

C_d = Coefficient of drag

F_d = Force of drag (N)

T = Torque about the center axis (Nm)

d = Distance to worst case center of pressure (m)

ρ = Density of water (kg/m^3)

V = Relative velocity of water (m/s^2)

A = Area of frontal face (m^2)

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Introduction

The C-TAB (Carp-Tracking Autonomous Boat) project is a joint effort by the Murray State University Biology Department and the School of Engineering. The goal of this project is to design and implement an autonomous vessel that can track and mark the location of a given carp in the Kentucky Lake region of Land Between the Lakes. This marine vessel is intended to be deployed at Hancock Biological Station by Murray State staff and or graduate students affiliated with the Biology Department. The work completed by C-TAB will contribute to a more comprehensive study conducted by the USGS and other universities in tracking and evaluating the movement of this invasive species of carp.

The manual studies of Bigheaded carp currently require the researcher to sit on a boat for hours at a time identifying and tracking Bigheaded Carp in Kentucky Lake. A hydrophone is used to “hear” a ping emitted from a tag on a fish. There are three different types of tags on the fish in Kentucky Lake, which emit their pings at three different time intervals. Those time intervals are forty-five seconds, one minute, and two minutes. Not knowing which type of tag could be in proximity of the hydrophone, investigators must wait a minimum of two minutes at a location before moving on. Two different kinds of hydrophones are currently used in the study. The omnidirectional hydrophone receives signals within a radius surrounding the device and is first used to generally localize a fish. After the omnidirectional hydrophone indicates a fish is in the area, a directional hydrophone is used to further localize the tagged fish. This directional hydrophone provides the researcher with the general direction of the tagged fish. This direction is described as a range of angles. If the directional hydrophone does not detect a tagged fish that the omnidirectional hydrophone previously heard, it is rotated to a new orientation and must wait a minimum of two minutes to listen for a ping from a tagged fish. This process is repeated until the researcher has determined the general direction of the tagged fish, which was initially detected by the omnidirectional hydrophone. Once the direction of the tagged fish is determined, the boat is moved toward the detected fish, and the process starts over at the deployment of the directional hydrophone. The signal strength of the ping measured in decibels is displayed on the VR-100 receiver box. This signal strength is logarithmically related to the distance the detected fish is from the boat. Increasing decibel readings indicate the boat is approaching the tagged fish. Once a threshold of 85 decibels has been reached, the coordinate location of the fish is recorded and shared with a national database.

Observation of the survey procedure detailed above indicated that its automation would be relatively straightforward. The areas of mechanical design, sensor selection, electrical assembly, and software development are where our group has advanced the foundation developed by the previous group of Engineering Physics design students. The mechanical design, electrical assembly, and software development were the responsibility of other team members; their research will be referenced, but not fully explored for this paper. This paper will focus on the sensor selection and gearbox selection, and the effects these systems have on C-TAB as a whole.

Object avoidance is necessary for safe navigation through Kentucky Lake. Running C-TAB aground is a legitimate concern due to shallow areas in the lake and the fluctuating water levels throughout the seasons. This issue is addressed through the implementation of a transducer used to read depth measurements. The transducer will alert the C-TAB when an unsafe depth is approached. This provides the basis for the object avoidance of C-TAB. Readings from the depth finder will be prioritized above all other sensors to ensure the safety of C-TAB.

Constraints

C-TAB is a continuation of work done by the Engineering Physics design team from 2021-2022, and their choices restrict the selection of the transducer. The boat design chosen by the previous Engineering Physics design team was a small pontoon-style boat. Mounting transducers on pontoon boats can be difficult because the tubes of a pontoons have few flat surfaces. Water turbulence introduced by the tubes of pontoons further limits transducer placement. Turbulence can cause errors in the accuracy of any transducer. Because of the uncertainty of turbulence induced by the hull, thru-hull transducers were not considered, as they would be positioned such that turbulence could interfere with their readings.

When considering replacing the VR-100, the cost was restrictive. The budget for the whole project was just under $3000. Currently, manual tracking of Bigheaded carp is done with a VR-100 receiver. The VR-100 costs approximately $8000. Less expensive substitutes for the VR-100 were found, but still averaged over the project budget.

Design Choices and Considerations

Carp Tracking Overview

The current carp tracking procedure involves three components: a transmitter, a hydrophone, and a receiver. The transmitters, commonly called “tags,” are attached to fish and send out pings at various programmed intervals. These pings operate at 69 kHz and carry the transmitter ID. The transmitter ID allows the researchers to know which species of fish they are following and help distinguish fish within the same species. The two types of hydrophones currently employed for manual tracking are the omnidirectional and the directional hydrophones. The omnidirectional hydrophone is used to generally localize a fish around the boat and the directional hydrophone is then used to pinpoint the location of the fish. If there is no signal interference, the receiver decodes the transmitter's ID from the signal received by the hydrophone; the receiver is also able to determine the strength of the signal. The data collected by this survey method will lead researchers to better understand the movement patterns of bigheaded carp.

Receiver

The VR-100 used by researchers to conduct the population surveys does not provide easy access to offloading the stored transmitter ID data. Automatic data retrieval of this data is essential to allow the autonomy of navigation toward known tagged fish. Initially, the team thought automation of the VR-100 was impossible. Many new, more easily automated, receivers were considered. Any potential replacement receiver needed to perform the two main functions of the VR-100, logging GPS coordinates and decoding received signals into transmitter IDs. Ultimately, we choose to keep the VR-100 because of the high cost of a new receiver; additionally, we were uncertain that a third-party receiver could decode the signals of the transmitters already in Kentucky Lake.

We determined that the autonomous transfer of data from the VR-100 to a connected computer was possible via preliminary testing. This automation was done through a Python script that moves the mouse to set positions on the screen to offload the data from the VR-100. This process was designed by another team member. A new constraint came from this decision as only one hydrophone was able to connect to the VR-100 at a time.

Choice of Hydrophone

Initially, we intended to utilize both the directional and omnidirectional hydrophones to track the location of fish. Using the VR-100 restricts the system to a single hydrophone. If C-

TAB relied solely on the omnidirectional hydrophone, its role would change drastically. C-TAB would no longer replace researchers manually conducting the surveys, but would direct their efforts by going before the researchers, generally localizing tagged fish, and reporting that information to the researchers. The precise carp localization would be done manually in this scenario. This new role was acceptable for the MSU Biology department. Taking this into consideration, the team decided to design C-TAB to perform surveys fully autonomously. Relying solely on the VH110 directional hydrophone, and altering C-TAB's data collection algorithm. With the directional hydrophone, C-TAB is able to complete all tasks that the researchers are manually performing in the field.

Depth Finder

Safe autonomous navigation through Kentucky Lake requires a system for the detection of underwater obstacles. Such detection requires a transducer that continuously calculates the depth of the water below the boat. This transducer must interface with the computer, have accurate readings for shallow depths of approximately 3 feet and deeper, and have an operating signal above 70 kHz. A depth finding transducer functions by sending out a signal wave to bounce off the base of the lake and recording the echo of the signal to calculate the depth. This signal of the transducer needs to be outside of the range of the hydrophone or it could interfere with the receiver trying to decode the ID from the transmitters on the fish.

With the former constraints in consideration, there were three choices within an acceptable price range. These options were a humminbird helix series fish finder, a CruzPro PcFF80 pc-based fish finder, and a CruzPro active transducer. The humminbird helix and PcFF80 are both programs connected to a simple transducer in which they log the data collected and display it on a screen. The difference between the two is the humminbird helix has a screen to determine and display depth data, while the PcFF80 runs a program on a computer to determine and display depth data. The problem with these choices was the ease of compatibility with the onboard computer system. The PcFF80 requires a headless computing program similar to that of the one being used to offload the VR-100 data. Two simultaneous headless computing programs would cause too much interference as both programs would need control over the mouse at the same time. The humminbird helix requires a cable to be hooked into the circuitry of the display screen to intercept the data it calculates before it is displayed on the screen. These options lacked the efficiency necessary to properly function for underwater object avoidance.

The third option was chosen. The CruzPro active transducer calculates the depth data as soon as the echo is recorded and can send the depth data to any connected system. This transducer provides easy access to the depth measurements of all three possible choices. Due to the shape of the bottom of C-TAB, a transom mount active transducer was chosen over a thru-hull version due to interference that would occur with the placement of a thru-hull active transducer.

Gearbox

The understanding of the direction in which the hydrophone is pointed is critical for the navigation of C-TAB. The turning of the hydrophone is accomplished through a stepper motor, and every stepper motor has a holding torque. If the force created by outside factors causes a torque greater than the holding torque of the stepper motor then it will cause a slip. Currently, there is no way for C-TAB’s code to determine this has occurred. This slippage will cause C-TAB’s code to believe the hydrophone has turned more than it has, as shown in Figure 1. Once that angle is put through the part of the code for determining the motor input, it will send C-TAB in the wrong direction and possibly away from the fish.

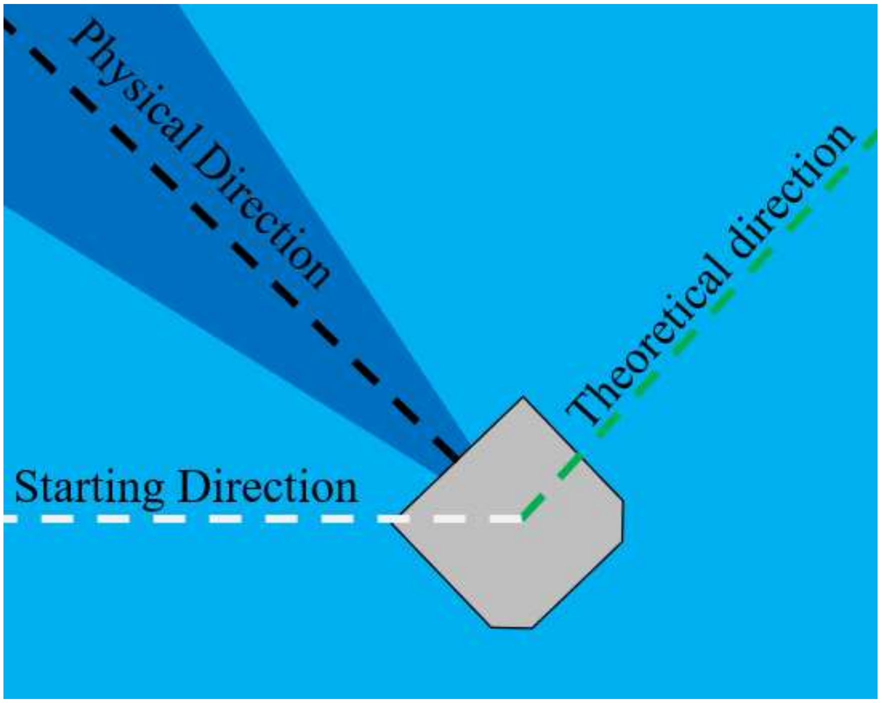

Fig 1. Diagram visualizing the difference between the theoretical direction from the physical direction due to missed steps

A gearbox is necessary to increase the base holding torque of a stepper motor. When a gearbox is attached the chances of losing a step are greatly decreased. A side effect of choosing a higher gear ratio is that the time it will take to rotate the hydrophone 360 degrees increases linearly with the gear ratio. This becomes a problem for listening to the pings of a transmitter. The transmitters send out signals in intervals between 45 seconds to 2 mins, and if the hydrophone does not rotate fast enough, there is a chance to miss the signal and its direction relative to C-TAB. To ensure no loss of step and the ability to rotate fast enough, a worst-case scenario of torque on the stepper motor needed to be conducted to find the minimum gear ratio.

Analytical Methods of Design

Torque and Gearbox

I chose a high torque Nema 17 with a 5:1 planetary gearbox to rotate the hydrophone in the water. The gearbox was needed to increase the holding torque of the stepper motor. The holding torque is important to make sure C-TAB can calculate which direction the hydrophone is pointing. A slipping motor shaft would cause a misalignment between the theoretical angle of the hydrophone and the physical angle of the hydrophone. As the gear ratios increase, the time to rotate to the commanded angle also increases. Too large of a gear ratio increases the risk of miscalculating the angle at which the fish is located if it is unable to rotate to position fast enough.

The Nema 17 stepper motor has a holding torque of approximately 0.45 Nm [4] and if the hydrodynamic forces on the arm piece, shown below in Figure 2a, cause a greater torque then there will be a chance of slip. The chosen gearbox ratio of 5:1 increases that holding torque to 2.0 Nm [4]. A Solidworks fluid simulation was done on this part of the hydrophone arm to determine the torque created. Several simplifying assumptions are necessary because of the complexity of this analysis. To ensure this does not affect the accuracy of the data collected a worst-case scenario analysis of C-TAB in normal working conditions is conducted. The following assumptions were made for the worst-case scenario analysis: the hydrophone arm and stepper motor will be under normal working conditions having no foreign objects interfering with the rotation of the hydrophone, the largest coefficient of drag to be from water passing onto the side of the arm shown in Figure 2b, the buoyant force is to be neglected as this part of the arm is held underwater by the rest of the arm, the velocity created by the wind on the boat is to be neglected as C-TAB is a small boat and the wind should not have much effect in increasing its velocity, and the center of pressure, where the force of drag will act, is located on the furthest point from the center axis. This is represented by the green dot in Figure 2a which is 1.95 in, or 0.049 m, away from the center axis, d = 0.0495 m.

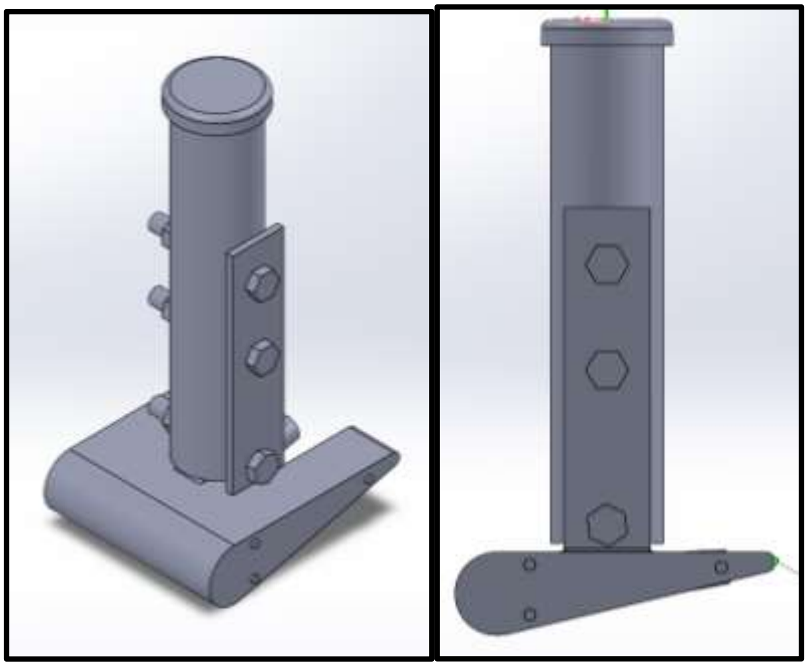

Fig 2**.** a) On Left, isometric view the part of the hydrophone arm which the stepper motor will be rotating b) On Right, shows the frontal area used in the calculation of the drag coefficient, C_d, as well as the worse-case scenario center of pressure, located at the green dot

The Solidworks fluid simulation represented in Figure 3, calculates the drag coefficient which can be used to determine the drag force. This is all calculated within Solidworks by monitoring the change in velocities of simulated water particles to determine the force on the arm, which then can be calculated into the drag coefficient.

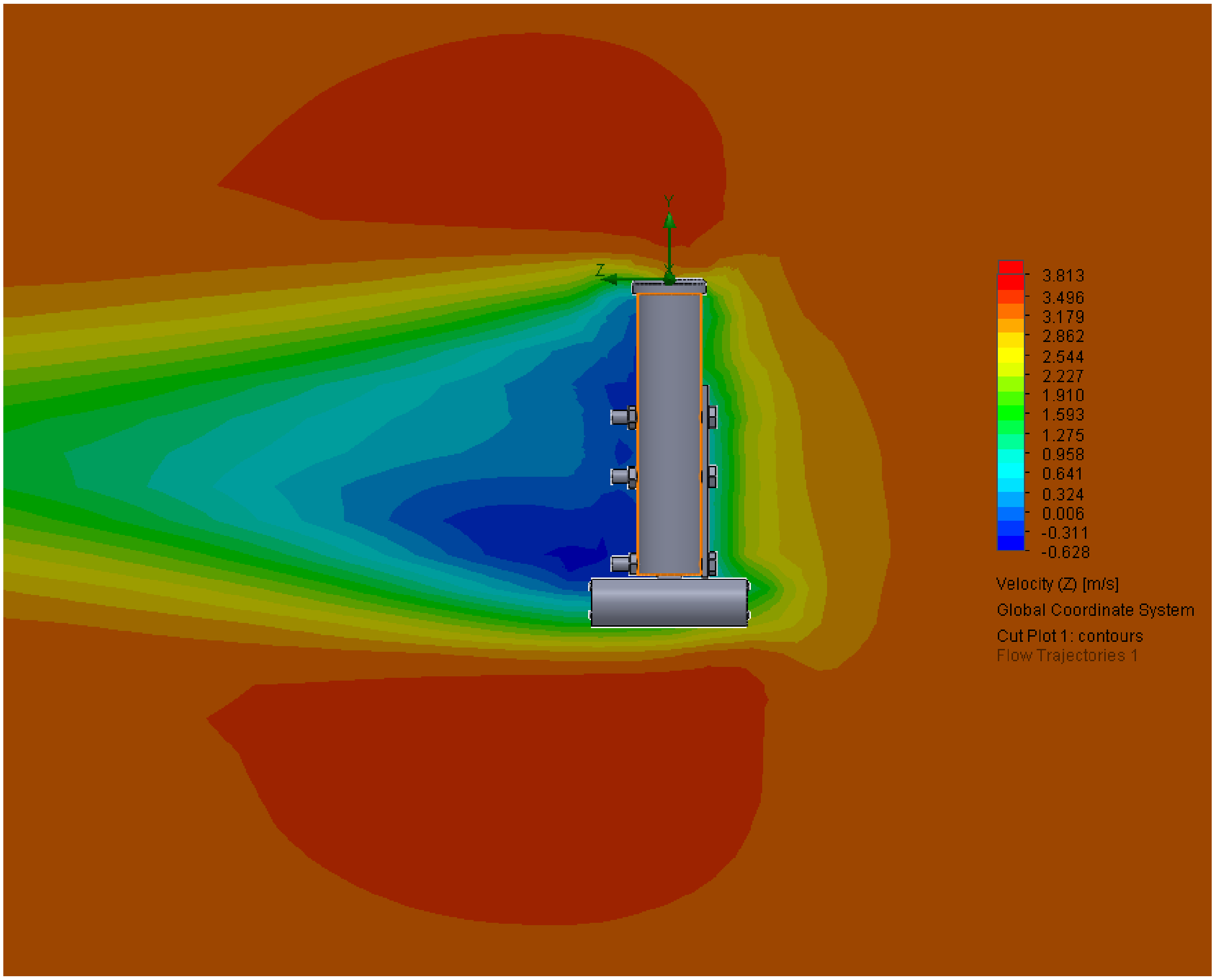

Fig 3. Velocity profile, illustrating how C_d was calculated by summing up the loss of velocity and momentum within Solidworks

The calculated drag coefficient is approximately 0.55, $C_d = 0.55$, for the frontal face of Figure 2b. The frontal face area is also calculated through Solidworks to equal approximately 14.89 inches^2 or 0.00961 meters^2, A = 0.00961 m^2. Using this coefficient in Equation 2, which is derived from Equation 1, the force of drag on the part is calculated. Assuming ρ = 997 kg/m^3, the density of water.

$$C_d = F_d/(1/2\rho V^2 A) \quad (1)$$

$$F_d = (C_d \rho V^2 A)/2 \quad (2)$$

Once the force of drag is determined, it can be put into Equation 3 to solve for the torque it creates about the center axis.

$$T = F_d * d \tag{3}$$

Using these equations in a custom Python script. It shows the possible torque created from various relative velocities of water, results as shown in Figure 4. The lower black dotted line is the holding torque of the Nema 17 by itself and the upper gray dotted line represents the holding torque with the gearbox with a ratio of 5:1 added onto the Nema 17.

The graph in Figure 4 below, shows that in the worst-case scenario, the gear ratio of 5:1 will not have enough holding torque if the relative velocity of the water exceeds approximately 3.9 m/s. Once the relative water velocity goes beyond 3.9 m/s the torque on the motor will always exceed 2 Nm which is the holding torque of the 5:1 gearbox. This can be neglected as the VH-110 directional hydrophone manual states that while the hydrophone is underwater to keep the boat it is connected to moving at a maximum speed of 5 knots [1], which is approximately 2.57 m/s. For the relative water velocity to be large enough to create a torque of 2 Nm, the top layer water current velocity must exceed approximately 1.3 m/s against the traveling direction of C-TAB. Kentucky Lake is an offshoot of the Tennessee River whose average daily water discharge is approximately 35000 ft^3/s [2]. As the Tennessee River narrows into Kentucky Lake, the water velocity increases. The expected highest water velocity will be around 1 m/s in normal weather conditions for which C-TAB would be sent out. Using the worst-case relative velocity of water of the C-TAB's max speed and the fastest speed of water in Kentucky Lake, 3.57 m/s, it does show the importance of the gearbox as the torque created on the motor would be approximately 1.6 Nm which is almost 3 times the holding torque of the base Nema 17 stepper motor.

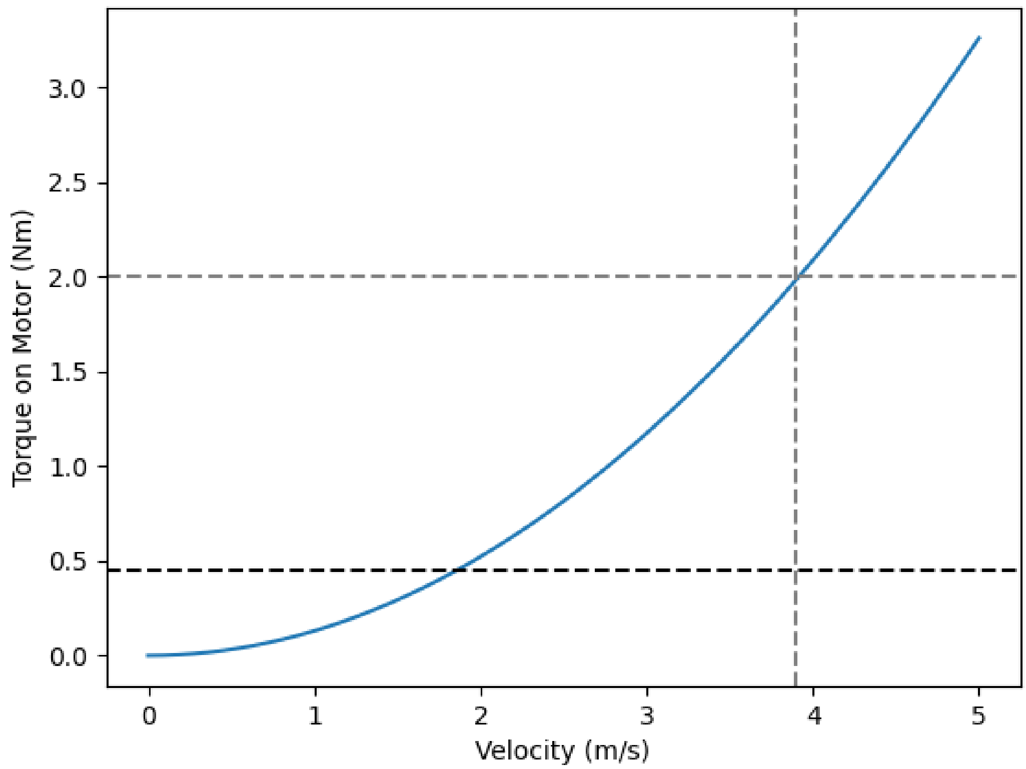

Fig 4. Graph that shows the relationship between the relative velocity of water and worst-case scenario torque

Initial Design for the Depth Finder

The ATT120A transom mount 450 ft active transducer from CruzPro LTD was chosen for it is the least expensive, interfaces the most directly with the on-board computer, and it operates at a frequency that will not interfere with any other signals. The transducer sends out a signal and receives the signal's echo to calculate the depth. The depth calculation is passed to the computer to be run through an emergency stop algorithm. The transducer needs to be connected to a 12V battery, the signal wire is to be connected to a DB9 RS232 serial port, a DB9 RS232 to USB converter is needed to interface with the on-board computer, and each circuit is connected to ground as described in Figure 5.

Wire	Connection
NMEA out	Pin 3 of RS232
Power	12V Battery terminal
Shield	Battery Ground
Signal Ground (Pin 5 of RS232)	Battery Ground

Fig 5. Diagram detailing the connections for the proper function of the transducer [3]

The transducers transmit the depth data in the form of NMEA sentences. NMEA sentences are standards set by the National Marine Electronics Association to ensure effective communication for all types of data between different companies' marine products. The ATT120A active transducer functions with NMEA 0183 sentences. The sentence structure for a depth reading is shown in the example below in Figure 6.

$SDDBT,015.7,f,004.8,M,002.6,F*0D

Fig 6. NMEA 0183 sentence which can be gathered from the transducer's connection to a computer

Sentences like the one in Figure 6 contain different units of measurement for the same depth reading. These units include feet, meters, and fathoms. The above sentence in Figure 6 details a depth reading of 15.7 feet, 4.8 meters, and 2.6 fathoms. The ATT120A active transducer can read water temperature as well as depth. The start of the sentences distinguishes between the different types of data. Depth data starts the sentence with $SDDBT, as shown in Figure 6, while the sentences of water temperature data start with $SDMTW.

As these sentences are received into the computer through the serial port, a Python script is to be written to record the data into a comma-separated variable (CSV) for use in the emergency stop program. Two Python scripts were the base design starting. The first script was to be programmed to collect depth readings and sort them into a CSV, while part of the main script of C-TAB would read the Excel sheet after a short period. A general flow chart for the script is shown in Figure 7.

The depth finder will receive data at a faster rate than any of the other sensors; a moving average window will be used to keep the data being read minimally. A moving average window replaces the current measurement with the average of a set number of recent data points. This average will allow C-TAB to function when false positives are created by various objects reflect the signal such as a school of fish. If the average of the window is smaller than the cut-off depth, then C-TAB will go into emergency stop procedures. The emergency stop procedures are to turn off the logic of C-TAB. When the logic is turned off C-TAB will be left stranded in the lake, but will no longer be moving itself to an unsafe depth. This is a temporary solution, once C-TAB is more developed than it should be designed to restart itself once it detects it has returned to a safe depth or be able to navigate away from the unsafe depth.

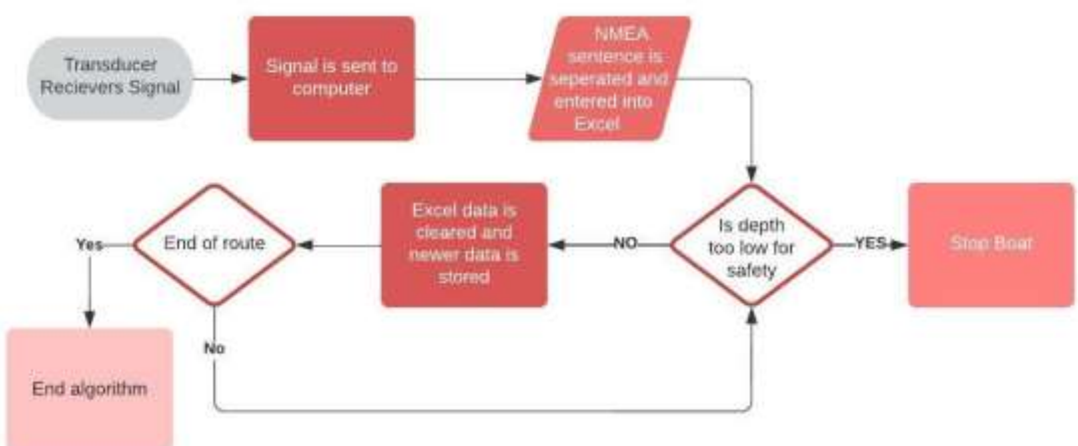

Fig 7. Flow chart explaining the coding path of how to get the important depth information readable

Implementing Chosen Designs

Overview

My work with the Nema 17 calculations and design was limited to the analysis done during the fall semester of 2022. The analysis done will provide a basis for the construction of the hydrophone arm. The construction of the hydrophone arm was distributed to two other team members. The spring semester of 2023 has largely involved implementing the depth finder. I have also assisted other team members with tasks that proved more complicated than originally designed.

Connecting the Depth Finder

Changes to the Logic

Once testing with the depth finder was successful, a change of the logic path was necessary. The use of two scripts to activate the emergency stop was inefficient. The time it took for the main code of C-TAB to start reading the data after completing all steps first could cause C-TAB to damage itself in an unsafe depth. The reading of the transducer data and the emergency stop procedure were combined to always run alongside the main code of C-TAB. The original logic flow for the emergency stop procedure, detailed in Figure 7, had to be reworked. The new script is to still implement both the storage of data points into a CSV file and the emergency stop procedure.

The largest change from the preliminary design to allow for more efficiency is the elimination of the need to read off a CSV file. The use of a CSV file is still implemented into the new Python script for two reasons. First the implementation of water temperature readings calculated by the ATT120A active transducer will allow C-TAB to conduct this research data point while locating fish. Second, the CSV file will be used for troubleshooting. Every depth data collected will be sorted into this CSV file. In the case C-TAB runs aground or collides with an underwater obstacle, the person in charge of C-TAB will be able to investigate the CSV file to see where and how the emergency stop procedure failed. The use of a CSV file can be taken out of the script if needed and the emergency stop will still function as programmed.

The basis of the NMEA 0183 sentence reading and emergency stop procedure is an infinite loop. This infinite loop functions by using a Boolean variable and checking to see if it is false. The variable is initially set to false to allow the script to wait for the next incoming data into the serial port. As NMEA 0183 sentences come in there are two paths the code can take. If the NMEA 0183 sentence starts with $SDMTW the water temperature reading is then stored and the code restarts back at the beginning with the initial variable still set to false. The other path tests if the NMEA 0183 begins with $SDDBT. If the sentence does start with $SDDBT, the depth reading in feet is stored in the moving average window and the CSV file. If the data points in the moving average window exceed the programmed window size the oldest data point is eliminated. The script then checks to see if the moving average is less than the cut-off depth. The initial cut-off depth has been set to 3 feet but can be changed within the code. If it is false then the initial variable remains false and the loop continues. If it is true, then the initial variable is set to true, and the code exits the circular logic. The script is no longer looking for any incoming NMEA 0183 sentences from the serial port, and it alerts the main code of C-TAB to stop all functions.

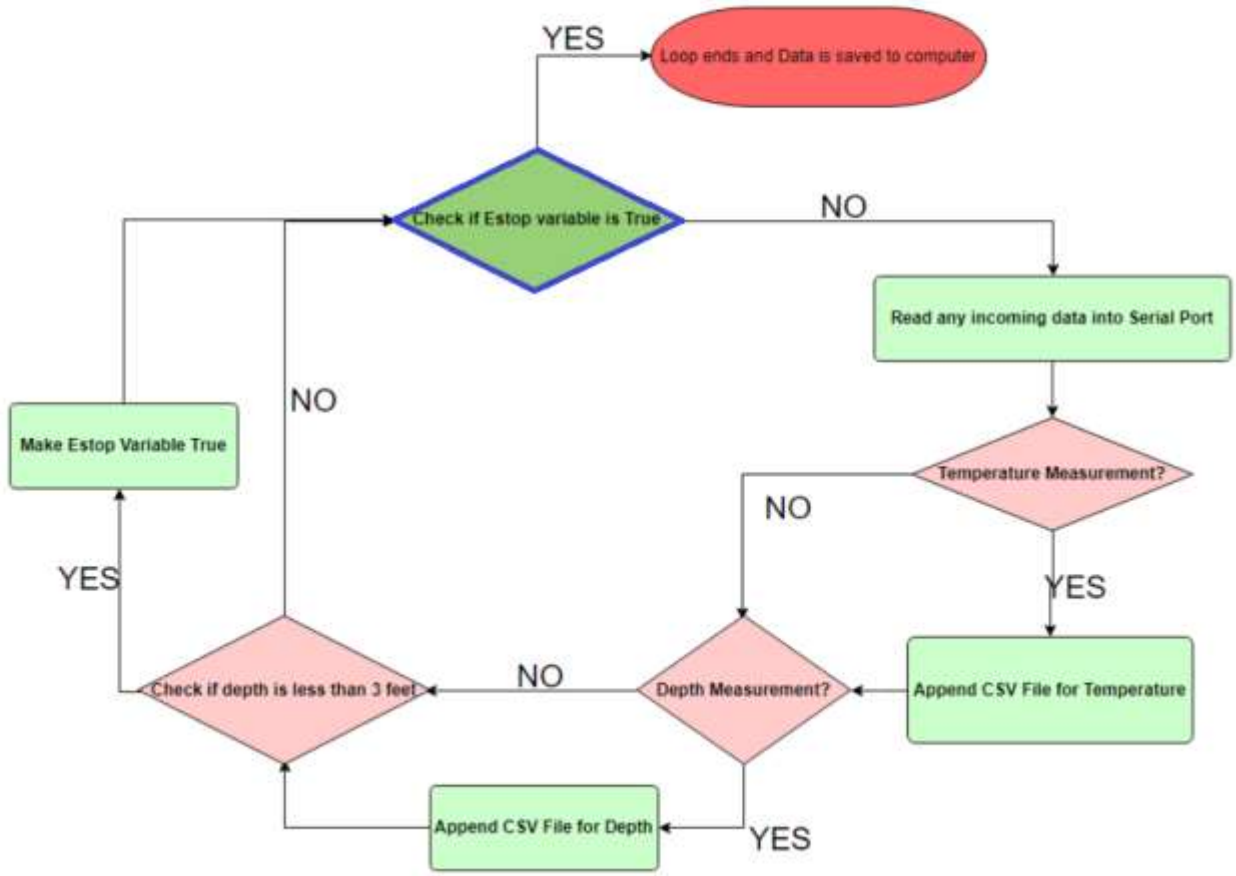

Fig 8. Flow chart showing the circular logic path of the incoming transducer data points

Python Script

The Python script implements three Python libraries. Those libraries are Pyserial, pynmea2, and pandas. Pyserial informs the program when incoming data is available. Pynmea2 parses the NMEA0183 sentences, e.g. Figure 6. Pandas writes the parsed sentence as data in a CSV file; this saved data will function as a black box in the event of system failure.

Once connected to the transducer through the correct computer port, the code will run as fast as the NMEA 0183 sentences come in. The code is written to always be ready for new incoming data after old data has been parsed and sorted. A sample result from the code is shown in Figure 9, where various checking points are displayed before it displays the depth in meters.

```
Test Point 1
$SDDBT,015.7,f,004.8,M,002.6,F*0D
Test Point 2
$SDDBT,015.7,f,004.8,M,002.6,F*0D
4.8
```

Fig 9. Sample data that was collected from a test run of the Emergency Stop code

Wiring the Depth Finder

Waterproofing of the connection between the transducer and the computer was achieved via male and female RS232 connections. The transducer signal wire is soldered to the red wire which corresponds to pin 3 on the male RS232. The yellow ground wire and the shield wire of the RS232 are both soldered together and connected to the battery ground on C-TAB. The male RS232 is attached to the female RS232 port connecting the male pin 3 to the RxD pin on the female RS232. The RxD pin shown in Figure 11 is the pin for receiving incoming data [5].

Male DB9 RS232	
Pin Number	Wire Color
Pin 1	Black
Pin 2	Brown
Pin 3	Red
Pin 4	Orange
Pin 5	Yellow
Pin 6	Green
Pin 7	Blue
Pin 8	Purple
Pin 9	Grey
Shield	No Color

Fig 10. Wire colors of the male RS232 and their corresponding pin

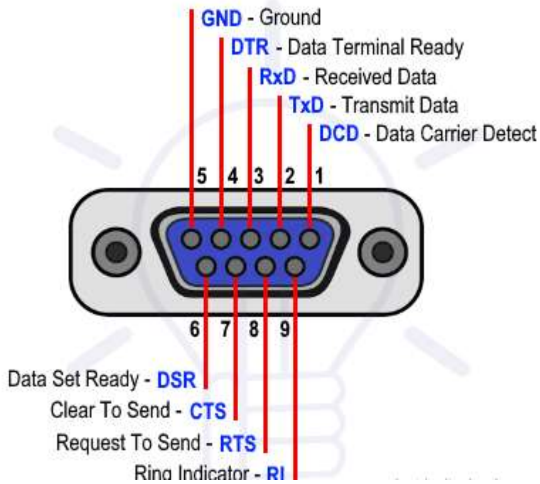

Fig 11. Pin layout of the female DB9 RS232 [5]

Power to the transducer is by the connection of the red wire from the transducer to a 12v DC battery and the shield wire to the battery ground on C-TAB. For testing, a battery supply was used, as shown in Figure 12. The battery supply allowed for safe testing of the transducer. The testing with the transducer yielded the results shown previously in Figure 9. Now the transducer is securely connected to the boat and all soldered connections are contained within a waterproof box on board C-TAB.

Fig 12. The setup for testing with the hooked-up transducer

Mounting the Depth Finder

C-TAB is a small pontoon-style boat. Transom transducer placements are limited on pontoon boats as these transducers are designed to be placed near the motor at the stern of the boat to reduce the effects of turbulence on the readings. This location is not possible for many pontoon boats. My initial plan for the placement of the depth finder was at the bow of C-TAB. Since C-TAB was not traveling at fast speeds, the turbulence created at the bow of the boat would have minimal to no effects on the depth readings.

The design later changed to mount the hydrophone arm to the bow of C-TAB. To avoid any physical interference, the depth finder is mounted on the hydrophone arm. This new placement is accounted for in the Python code as a new variable to calculate the cut-off level for the emergency stop. This new constant is the distance from the hydrophone from the transducer, which they are approximately 1 foot apart.

The new design has the concern of signal interference. The transducer operates at a signal of 120 kHz. This is almost two times the frequency of the transmitters, which operate at 70 kHz. Theoretically, the two signals should have minimal to no interference. Interference was tested between the two systems in Kentucky Lake to ensure there will be no type of interference. The transducer was hooked up to power and placed at various heights above a hydrophone while a transmitter was pinging off in the distance. The hydrophone could hear the depth finder functioning, but the signals from the depth finder did affect the transmitter's signal strength or its ability to be decoded by the VR-100. More testing may be required to understand the effects on the transmitter signal that the depth finder has.

Future Testing

Two factors need to be tested for this transducer setup. Both must deal with the accuracy of the depths it calculates. As this is still an ongoing project these have yet to be done, but will need to be completed to ensure proper safety of C-TAB.

The first test is for the overall accuracy of the transducer. It needs to be known if the transducer can get consistent depth readings with a small deviation or none. C-TAB will be navigated to various locations in Kentucky Lake with known depths. These known depths will need to be varied from 3 feet and above to ensure accuracy at all depths. C-TAB will then sit in place to send its depth readings to a CSV file. Using this CSV file and the known depth a confidence interval can be calculated for the accuracy of the transducer.

After concluding the first test, the transducer may need to be angled differently. The transducer needs to be at a certain angle to the water surface. According to the manual that came with the transducer, this varies from boat to boat as the weight on every boat is distributed differently. A similar test to the first test is to be conducted. C-TAB will be taken out to a known depth and sit there taking depth readings with the new angle. This test will be repeated until the angle that produces the most accurate depth reading is determined.

Conclusion

Tracking carp without human intervention is a multilayered challenge that requires creativity and teamwork to resolve this unique problem. For the 2022 to 2023 team's efforts of tracking down bigheaded carp, great strides have been made to make it a reality. This project is a culmination of a year of thorough and dedicated work. The implementation of a headless computing system for C-TAB, the organization and rewiring of old and new electronic components, the designing and constructing of an arm to hold and turn a hydrophone underwater, and the use of a transducer as a depth finder have been successful. The importance of the sensor choices continues to impact many of the design choices of this project. The entire design of C-TAB now revolves around the use of the VR-100 and a directional hydrophone to pinpoint the location of a tagged fish. This will be accomplished with the Nema 17 stepper motor with the 5:1 gearbox. The gearbox is used to avoid the torque effects of water flowing water pressure on the part that will be rotating. Without the gearbox in normal working conditions, C-TAB could miscalculate the direction the hydrophone is pointed. With this miscalculation, C-TAB will navigate along a trajectory that could lead it away from the fish and into unsafe depths. If this worst case were to ever occur, then the newly implemented emergency stop procedure will stop C-TAB before it could damage any important equipment. The emergency stop procedure uses the ATT120A transom mount active transducer, which is mounted to the hydrophone arm by a bracket designed by another team member. The emergency stop code will shut off all systems of C-TAB when the transducer detects a depth of less than the chosen cut-off depth. Once the emergency stop is activated, it will leave C-TAB without the ability to navigate itself out in open water. This is a temporary solution; it will need to be updated to allow C-TAB to once again regain function after a safe depth is reached.

The effectiveness of this procedure will be tested in a controlled environment once all systems have been fully developed and merged onto C-TAB. The emergency stop procedure will be tested alongside the effectiveness of the ping tracking algorithm created by another team member. These two critical systems will be tested in a controlled environment by the Hancock Biological Station dock. An artificial fish will be created by moving a boat out into the water of the docking area with a tag attached underneath it. C-TAB will then be launched and all systems started. For the goal of effectively tracking down the artificial fish, the work done on the stepper motor and the emergency stop procedure need to function as they were each designed. Testing will be complete when it is shown that the stepper motor will not lose a step due to water pressure and C-TAB will not run aground during that time.

This project of updating C-TAB is still a continuing project and it will still need to be updated by the next year's graduates of the Senior Engineering Design class. Updating the stepper motor with an encoder will allow C-TAB to ensure the angle of the transducer if C-TAB enters improper working conditions, such as a fish colliding with the hydrophone. The final efforts of object avoidance will also play a critical part in their designs. With an underwater emergency stop designed and implemented by me this year, they will need to finish implementing the above-water object avoidance as well the ability to reset C-TAB into a safe position after the emergency stop has kicked in. These systems, once integrated, will make C-TAB one large step closer to living up to its name.

References

[1] AMIRIX Systems Inc., "VH110 and VH180-D Directional Hydrophones", 4876-03 datasheet [Online]. 2015. http://www.oceans-research.com/wp-content/uploads/2016/09/directional-hydrophones

[2] *National Water Information System*. USGS 03609500 Tennessee River near Paducah, KY. (n.d.). https://waterdata.usgs.gov/nwis/inventory/?site_no=03609500

[3] CruzPro Active Transducers, "CruzPro NMEA 0183 Active Depth, Temperature Transducers with NMEA 0183 Output", *cruzpro.com*. [Online]. Available: http://www.cruzpro.com/active.html. [Accessed 22 Nov. 22].

[4] *Stepper Online. (2023, May 1). Full Datasheet Nema 17 Stepper Motor Bipolar L=48mm w/ Gear Ratio 5:1 Planetary Gearbox.*

[5] Technology, E. (2020, May 6). *What is RS232 Serial Communication Protocol and how it works?* ELECTRICAL TECHNOLOGY. Retrieved April 18, 2023, from https://www.electrical technology.org/2020/05/rs232-serial-communication-protocol.html

[6] Oceans Research., *VR100 User Manual*, Vemco Inc. [Online]. Available: http://www.oceans-research.com/wp-content/uploads/2016/09/vr100-manual.pdf. 2015.